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Electric vehicle charging infrastructure in Poland

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A R T I C L E I N F O

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A B S T R A C T

This article describes the current state of development and future direction in the market for electric vehicles in Poland, with respect to the charging infrastructure. The authors have concentrated above all on the assumptions and results of ventures to-date in this field. There has also been conducted an analysis of the influence of electric vehicle development, in part concerning the charging infrastructure, on the Polish power system. In addition, this article outlines the potential for using electric vehicle charging terminals, in developing Semi Smart systems at the level of low-voltage distribution grids.

Contents

1. Introduction

The beginning of the 21C in the field of transport in Poland is characterised by a meagre growth in interest for electric vehicles (EV). In the first decade the growth has largely been confined to the level of end user – amateurs who, joining the general trend of reducing the negative impact on the natural environment [1–4], have carried out expensive conversions on cars using internal combustion engines to ones equipped with electric motors. Large motor corporations seeing this growth in interest, and in addition the continuing rise in fossil fuel prices, have produced models especially for such customers. At the present moment it is difficult to find any motor corporation not having among its range of vehicles at least one model driven by an electric power unit.

A fundamental factor limiting the development of electric vehicles has been the lack of an appropriate batteries with a sufficiently large duration and capacity of energy, enabling the deployment of a satisfactory range and quick replenishment of energy. Intensive work in the field of lithium cells has now resulted in its first success, if only in the form of the development of $LiFePO_4$ and other technologies enabling fast charging and reduction of battery weight [5,6]. At the same time there have been developed standards for the charging of batteries for electric vehicles [7], and the first charging systems are just being introduced.

With respect to the changes concerning the method of powering mechanised vehicles, in Poland there is being ushered in an Initiative in the building of a system for charging electric vehicles. Moreover, the development of electric vehicles in Poland is one of the factors taken into consideration in the building of Smart Grid type grids in Poland [8,9].

Taking the above into consideration, this article describes the basic assumptions concerning the Polish infrastructure for

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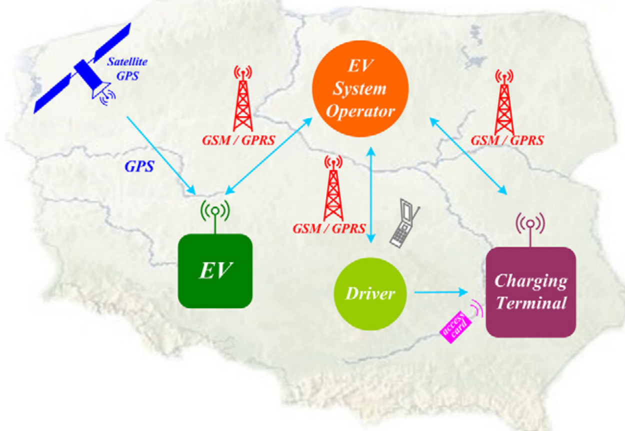

Fig. 1. Communication in the EV charging system in Poland.

charging electric vehicles, as well as an analysis of the influence of electric vehicles, in part concerning the charging infrastructure, on the Polish power system. The article also outlines the potential for using electric vehicle charging terminals for the building of Semi Smart systems at the level of low-voltage distribution grids.

2. Polish Initiative for the development of the electric vehicle market–main goals

The programme currently being realised in Poland, "Construction of the market for electric vehicles, their charging infrastructure – basics of energy security," is supported by European Union funds under the Operational Programme – Innovative Economy. This Initiative is focussed on the consolidation of the activities of the scientific and industrial communities in the direction of building an electric vehicle sector, while at the same time increasing the energy security in Poland. As is well known, the Polish energy sector is supported mainly by native black and brown coal deposits, while transport uses primarily imported liquid fuels [10,11]. Transferring, therefore, the energy sources utilised for transport may increase the national energy security, freeing users from imported fuels. However, on the other hand, in the situation in which the Polish power system is based on antiquated and overexploited installations, where there is not too much power generation in reserve, it is difficult to talk of increasing energy security, while increasing the load on such a power system. Therefore, the aim of the Initiative is also the building of a balanced system for charging electric vehicles, supported by renewable energy from distributed sources.

3. The structure of the Polish EV charging system

In the conception of the electric vehicle charging system the location, quantity of charging terminals and their type are specified.

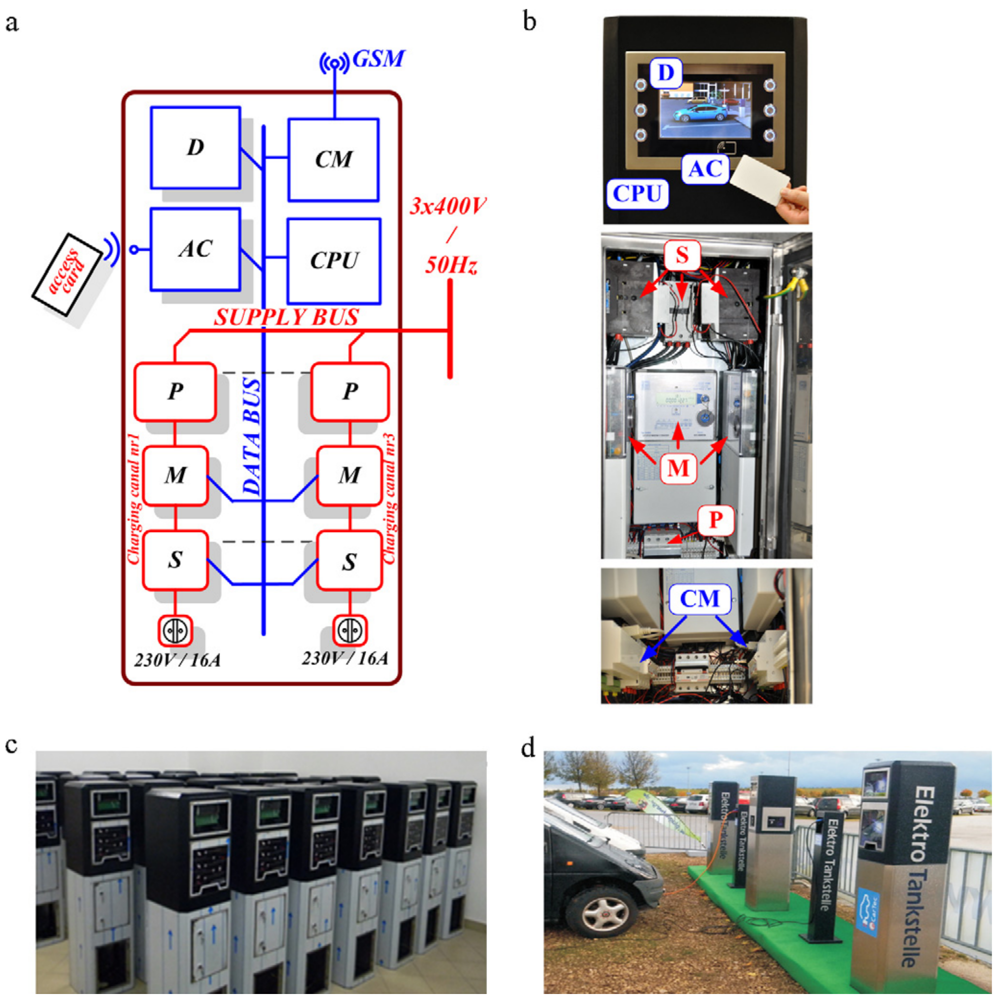

Fig. 2. City terminal: (a) functional diagram of terminal, (b) view during installation and activation, (c) practical realisation [12], and (d) demonstration at trade fairs. Legend: D – display, CM – bi-directional communication module, CPU – central processing unit, AC – access control module, P – protection, M – metering, S – status reading/setting.

Established in the framework of the Initiative are 330 city (public) charging terminals, 20 garage terminals, and 20 terminals with bi-directional energy flow [12]. Public terminals are distributed in five Polish cities: Warsaw, Krakow, Katowice, Gdansk and Mielec. An element of the charging system is also a centralised accounting-access system, which is based on a bi-directional exchange of data between individual participants of the EV system. Exchange of data within the structure of the above mentioned system takes place via GPRS, and coordination is carried out by the central office, as presented in Fig. 1.

3.1. Characteristics of charging terminals

As is described above, in the framework of the Initiative two major types of terminals have been developed, differing from each other in the location installed:

(a) city terminals, installed in public places
(b) garage terminals, installed in the houses of drivers (users).

In respect of the design, the two types of terminals do not differ significantly from each other. The only difference is the number of charging sockets, which in the garage terminal permits the charging of only one vehicle at a time, while in the city terminals three vehicles at a time may be charged.

The technical infrastructure of the terminals under discussion can be divided into two levels: the electrical, responsible for the distribution of electric energy, metering and protection; and computing, responsible for the control, metering–billing, communications and authorization functions. Detailed functional diagrams of the individual terminals are duly presented in Figs. 2a and 3a.

3.1.1. City terminal

This terminal possesses three independent charging sockets, each equipped with an independent metering and protection system. The whole terminal is managed by one central processing unit

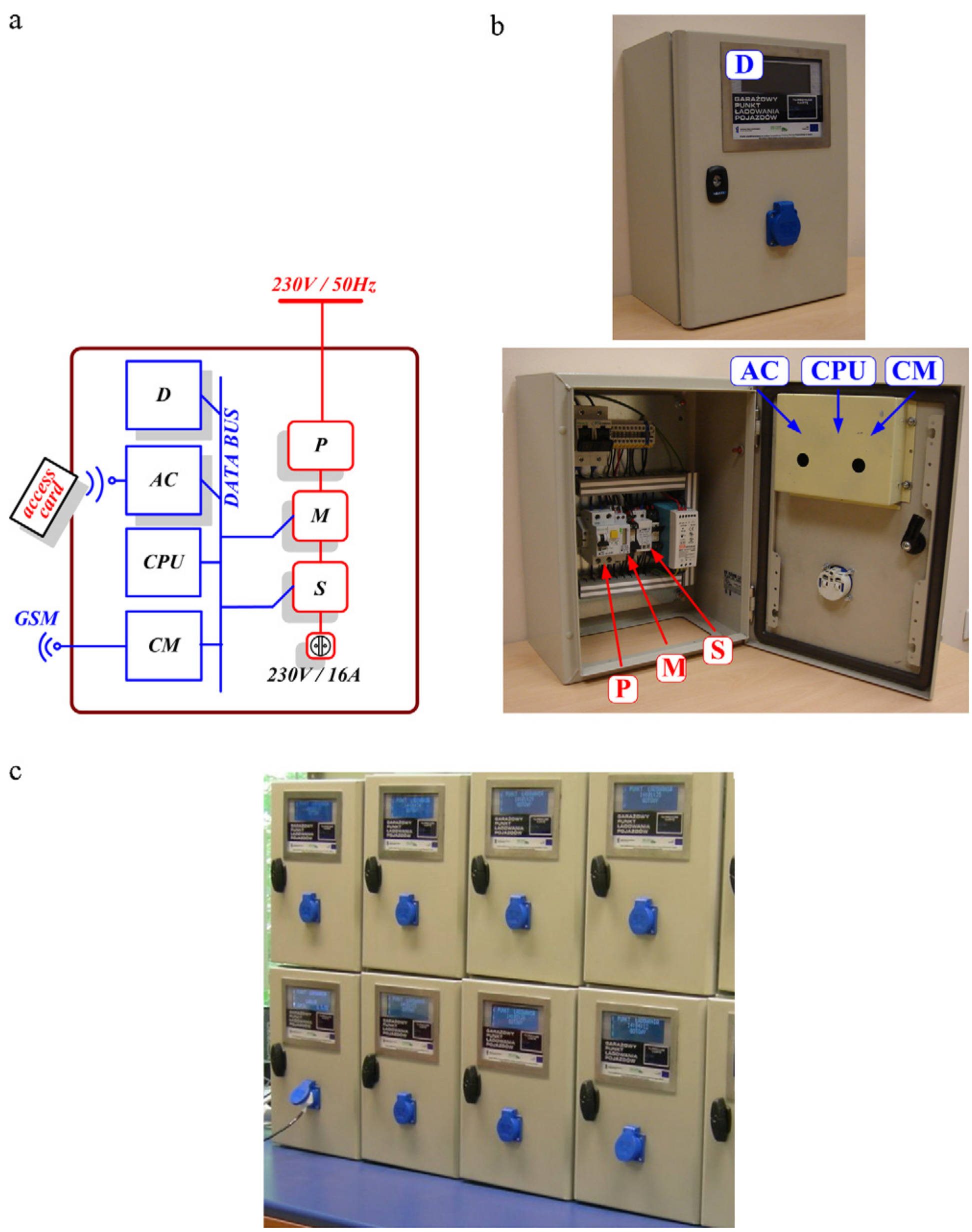

Fig. 3. Garage terminal: (a) functional diagram of terminal, (b) view during installation, and (c) testing [12]. Legend: D – display, CM – bi-directional communication module, CPU – central processing unit, AC – access control module, P – protection, M – metering, S – status reading/setting.

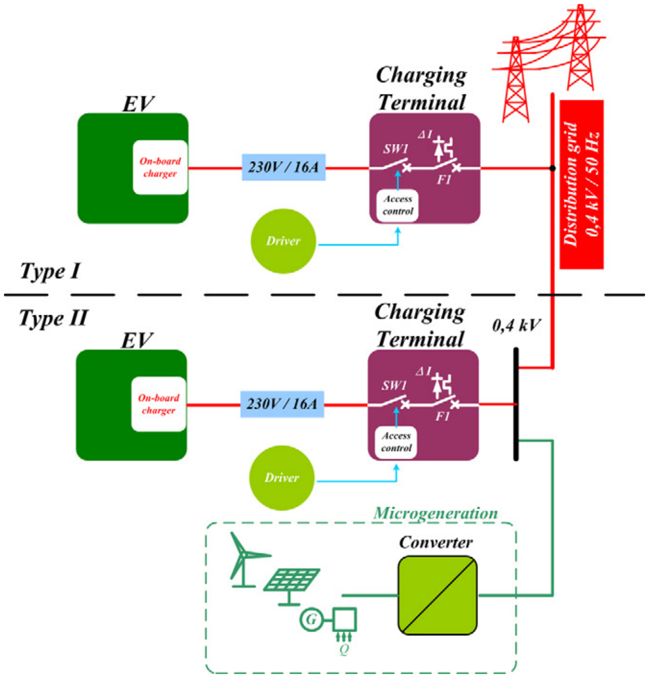

Fig. 4. Energy structure of the Polish EV charging system.

(CPU), which equally fulfills the control function (over the data bus signals) as well as managing access to the sockets, on the basis of information received from the client's access card, after its previous verification by the EV system operator (EVSO). The central processing unit also changes the position of the status switches, controlling the sockets of the charging circuit, and sends data to the EVSO on the protection status and on the position of the status switch. Return information for the terminal user, e.g., about free charging sockets, is conveyed by means of a display screen.

After completing charging, information about electric energy consumption is sent to the EVSO, who communicates with the user by means of SMS text service.

3.1.2. Garage terminal

The functionality of the garage terminal is similar to the city one, while a difference lies in the fact that it possesses only one charging socket. In addition, taking into account the location of installation, these terminals have a casing without any special vandal-proof construction.

In spite of the designation of garage terminals for use in internal electrical installations of the end user (behind a central billing device), they are equipped the same as city terminals with accounting-access devices. This results from the assumptions of the Initiative, which under the realisation of the project give free access to users of energy for the charging of electric vehicles. It concerns solely the recording and global accounting between the EV system operator, and the electric energy Distribution System Operator (DSO).

3.2. Charging terminal power supply types

In the framework of the EV charging system the individual terminals can have one of two types of power supply, as presented in Fig. 4.

In heavily urbanised locations (city centres) charging terminals are powered with Type I configurations, using the 0.4 kV public distribution grid. Unfortunately, further development of this type of power supply in the Polish conditions has been met with resistance on the part of the electric energy DSO, whereby it demands an analysis of the charging terminal influence on the parameters of the distribution grid at the point of connection.

On the other hand, on lightly urbanised territories (e.g., city suburbs), individual terminals are powered with Type II configurations – where terminals are additionally supported by local sources of energy (q.v., Fig. 4). EV charging terminals powered according to Type II configuration, do not "differentiate" the type of electric energy source (distribution grid or micro grid with renewable energy sources), and the balancing of energy takes place in a natural way, as is presented in Fig. 5.

Type II configuration, built into the framework of the Initiative, uses wind and solar (photovoltaic) energy sources, and in the future energy generated in the process of biogas combustion too. The choice of source used is decided by environmental conditions or the energy resources in the area where the given terminal is installed.

It is equally worth paying attention to the fact that in regard to the variation of particular regions of the country (in which the cities participating in the Initiative are located) in the scope of their renewable energy sources potential, together with charging terminals powered with Type II configurations, there have been provided generally accessible data bases (knowledge platforms) with information on the state of the natural environment. These knowledge platforms contain on-line accessibility to information such as wind direction, humidity, and temperature; and they constitute data bases on energy resources of a given region, thereby stimulating development of dedicated power supply types, utilising renewable energy sources in a given territory of Poland (q.v., Fig. 6).

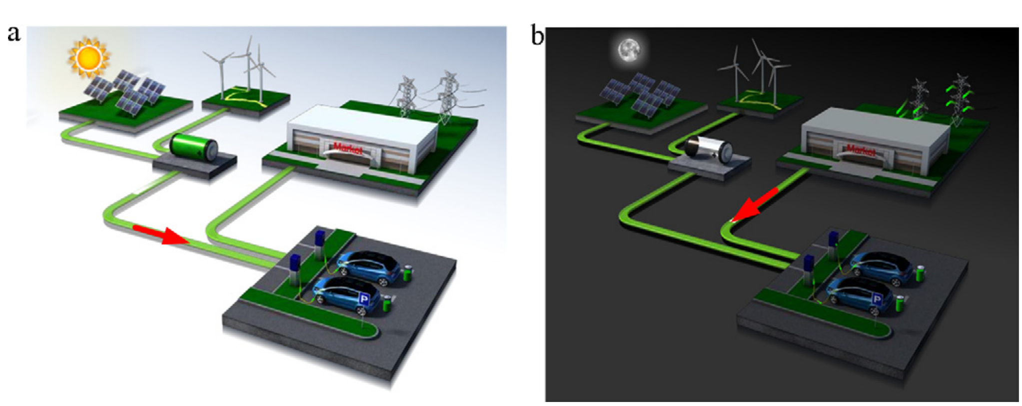

Fig. 5. Using local renewable energy sources to supply EV charging terminals: (a) with a positive balance of renewable energy, and (b) with an insufficient quantity of renewable energy.

Fig. 6. From the left: hybrid power station (using as an energy source the wind and sun) supporting Type II charging system and a view of the knowledge platform.

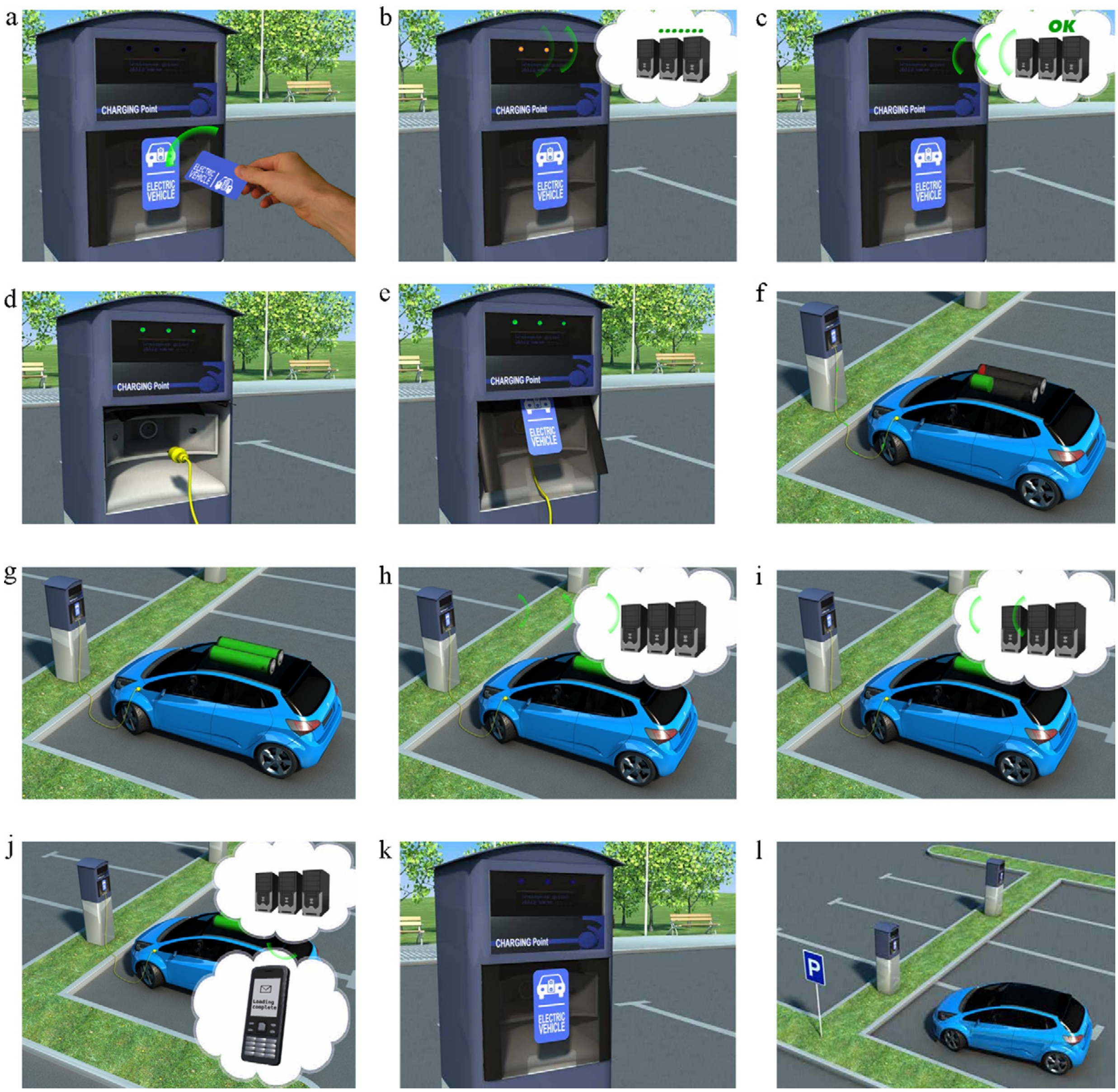

Fig. 7. Process of charging an electric vehicle [13]: (a) client identification, (b) authorization, (c) authorization confirmation, (d) socket access, (e) access protection, (f) EV battery charging, (g) end of charging, (h) transmitting data, (i) confirmation of receipt, (j) client notification, (k) access protection, and (l) release of terminal.

3.3. Communication and data acquisition system

All the elements of the electric vehicle charging system are connected within the GSM network, and the exchange of information is bi-directional. It should be noted that data sent to the individual participants of the charging system is controlled by the EV system operator; individual participants do not have the means of direct contact between each other. The exchange of information sent between the system units in the process of charging an electric vehicle takes place on several levels, as is shown in Fig. 7.

Exchange of data: charging terminal – EV system operator

The charging terminal sends to the EV system operator three classes of signals:

(a) about the technical status of the terminal, including information on the protection status or forcing of the blockade (an unauthorized attempt to gain access to the inside of the terminal),
(b) authorization, identification of the user on the basis of the magnetic proximity card (access card),
(c) information on the status of the charging process and use of electric energy by the authorized user (driver).

Exchange of data: EV – EV system operator

The electric vehicle transmits to the EV system operator two classes of signal:

(a) identification information and current location, on the basis of which a theoretical range is calculated,
(b) information from the internal Battery Management System (BMS) about the charging status (State of Charge – SOC) and the technical State of Health (SOH) of the battery.

Exchange of information: EV system operator – driver (user)

The exchange of information between the user and the EV system operator is transferred via two channels:

(a) the system user authorizes the charging process by means of a RFID proximity card containing identification information (authorization takes places via the terminal, in which there is located a magnetic proximity card reader), correct authorization allows access to the charging terminal and the charging process begins,
(b) in return, the driver (user) receives via the registered GSM telephone number by SMS service information on the status of the charging.

3.3.1. Semi Smart module for monitoring charging

Fig. 8 presents a curve of the daily load on the Polish Electrical Power System (EPS) determined on the basis of a prognosis for the winter of 2025 [14] and a curve of the volume of city traffic for the same year [15]. As will be noticed, there is a correlation of both facts and, which is bound up with this, the curve of daily load on the Polish EPS, in which the power drawn by the EV charging infrastructure has been additionally taken into account (in accordance with the assumptions made in [15], for the calculation of this graph, there was taken into account 1 million electric vehicles with an energy storage capacity of 30 kWh, with each of the vehicles covering a distance of 60 km daily).

Observing the curves presented in Fig. 8, it is noticeable that the extra loading on the power system caused by the EV charging infrastructure may be the cause of increased fluctuations in the daily loading on the Polish EPS. In order to avoid this phenomenon in the future, it will be necessary to forge active participation in the form of close cooperation of both local operators (EVSO and DSO). The coordinated actions of both operators can ensure optimal efficiency and stability for both the power system as well as the EV charging system [16–22]. The latter is possible to achieve, among other things, in the situation where the Distribution System Operator gains influence over the behaviour of drivers (EV charging system users).

The actions which the DSO may take to improve the distribution grid load profile are:

- system limitation, i.e., blocking/limiting the functioning of the charging terminals at appropriate times of the day.
- regulatory action on the demand for electric energy used for EV charging, via the design of a tariff system

System limits are aimed at maintaining reserve power during daily peak load at a level necessary for stable functioning of the power system (in Poland, in the instructions for exploitation of the transmission system it is defined as being at 14% of available power) and may be achieved through turning on/switching off (blocking/unblocking) charging sockets of individual terminals.

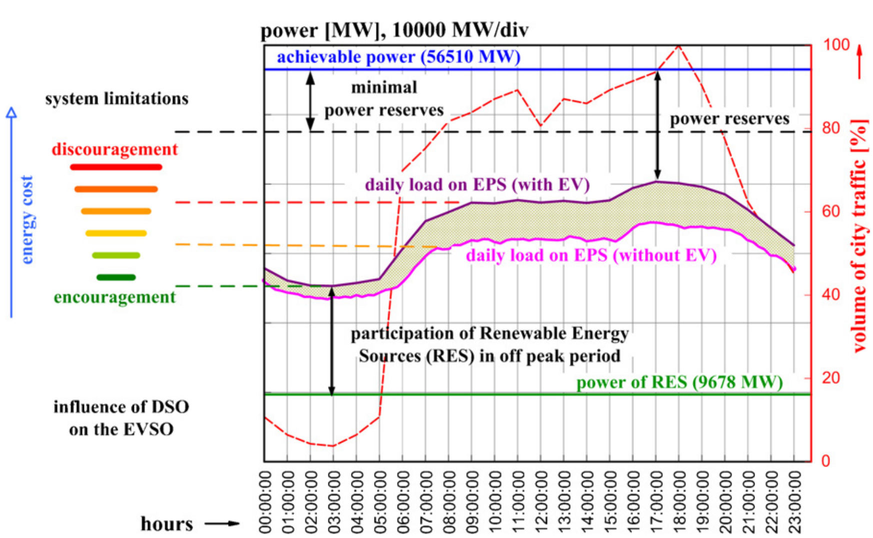

Fig. 8. Daily load on Polish Electrical Power System (winter period 2025) taking into account EV charging system loading (1 M EV/30 kWh) against volume of city traffic.

Fig. 9. The central screen of the Semi Smart module for monitoring charging, with the places marked for the location of the charging terminal groups, and the information on the display of the EV charging terminal, among other things, the possible choices for the tariff.

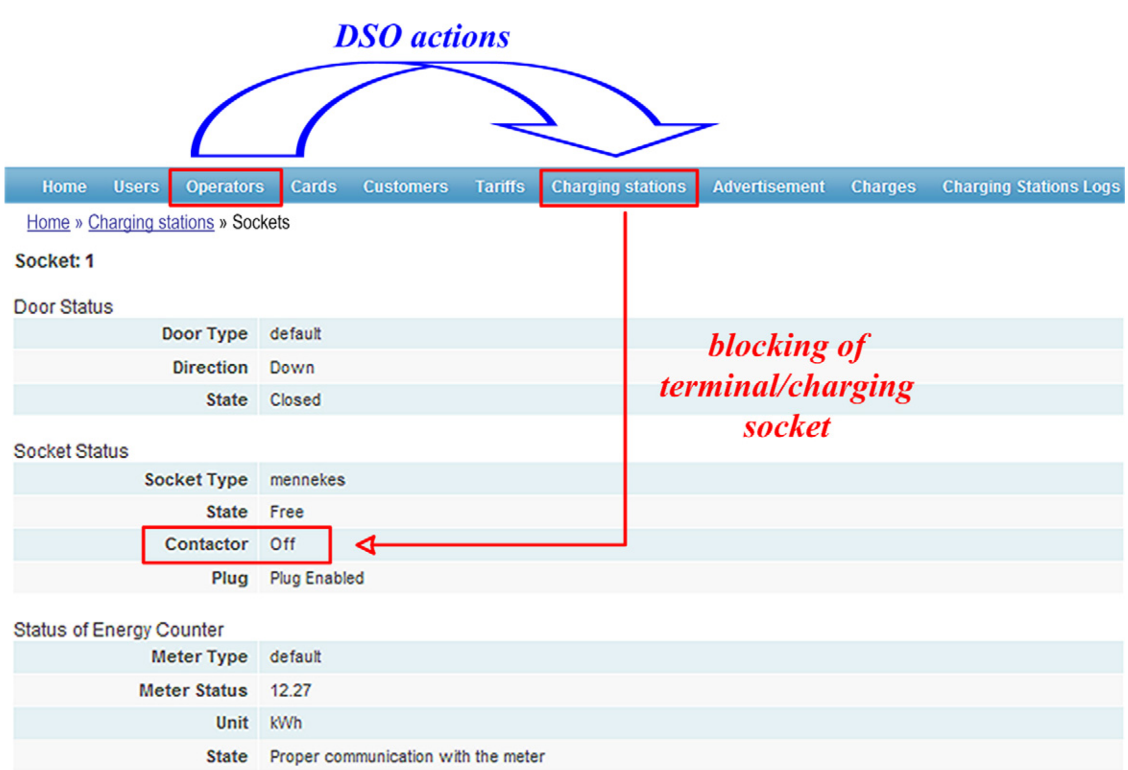

Fig. 10. The screen of the Semi Smart module for monitoring charging: DSO influence on the status of the charging socket.

Fig. 11. The screen of the Semi Smart module for monitoring charging: DSO influence on the tariffs.

The tariff system, in turn, should “encourage” drivers to charge electric vehicles during off-peak hours at night, by setting low charges for the electricity consumed, which will lead to a balancing of the daily load curve. In this way the establishing of tariffs should additionally fulfill the following conditions:

– the Distribution System Operator must have the possibility to change the tariffs within a full day on-line;
– the user (driver) must be aware of the choice of a more expensive tariff, as a result information about it must be available for the user at the moment of logging on to the system;
– the tariff must not change while charging is taking place.

The system of establishing individual tariffs should gain in importance in the future, i.e., in respect to the big contribution of renewables in the Polish power system. Since in the majority of cases the power of renewables is an unpredictable one, in view of its large contribution it may cause difficulties in maintaining quality standards in the power system (voltage and frequency variations). At the present moment the contribution of renewables in the Polish energy equation comes to about 5–6%, which in large part comes from hydro generators, however on the basis of the assumptions made in [14], their growth is predicted to be dynamic, especially in wind power.

Taking into account the above, within the scope of the earlier described communication and data acquisition system, the Semi Smart module for monitoring charging was developed (see Fig. 9). The Semi Smart module enables not only the realisation of the metering–billing functions – between user and EV system operator – but also communication with the Distribution System Operator. Thanks to the Semi Smart module the DSO can influence the work of the charging terminals by system limitations (Fig. 10) or a tariff system (Fig. 11), thanks to which it is possible to limit or increase the energy demand on the distribution grids at appropriate periods of the day – this type of solution in the Polish power system is new and may turn out to be the first step on the road to building intelligent power systems (Smart Grids) in Poland.

4. Conclusions

In Poland to-date there has been a lack of coherent policy in the area of electric road transport. In the documentation defining development plans for both the energy [14] and the transport [15] sectors there is a lack of clear plans in support of building an electric vehicle market. There is indeed a lot of space devoted to the support of actions aimed at improvement of energy efficiency as well as reduction of environmental pollution, yet the question of electric transport has barely been touched.

A light at the end of tunnel may turn out to be action undertaken within the frame of the Initiative, which has already led to huge interest in electric transport in Poland. There have appeared consortiums of companies in the transport, energy and power electronic sectors which are working on projects connected with the initiation of commercial charging terminals for electric vehicles, as well as fast-charging stations. It may be that the Initiative will not lead to the building of an electric vehicle market in Poland, however, the experience and information gained in the process of undertaking projects connected with it will allow the preparation in Poland of the necessary technical basis for the initiation of electric transport in the near future.

It seems, however, that the most important question in the building of an electric vehicle market, and the concomitant EV vehicle charging system, is the integration of activities in the energy and transport fields. Only symbiotic development of both systems can lead to the goal of a stable and reliable EPS, especially at the level of low voltage, and sustainable development of the Polish electric vehicle market.

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